ZEVs in Vehicle-to-Grid (V2G) Applications

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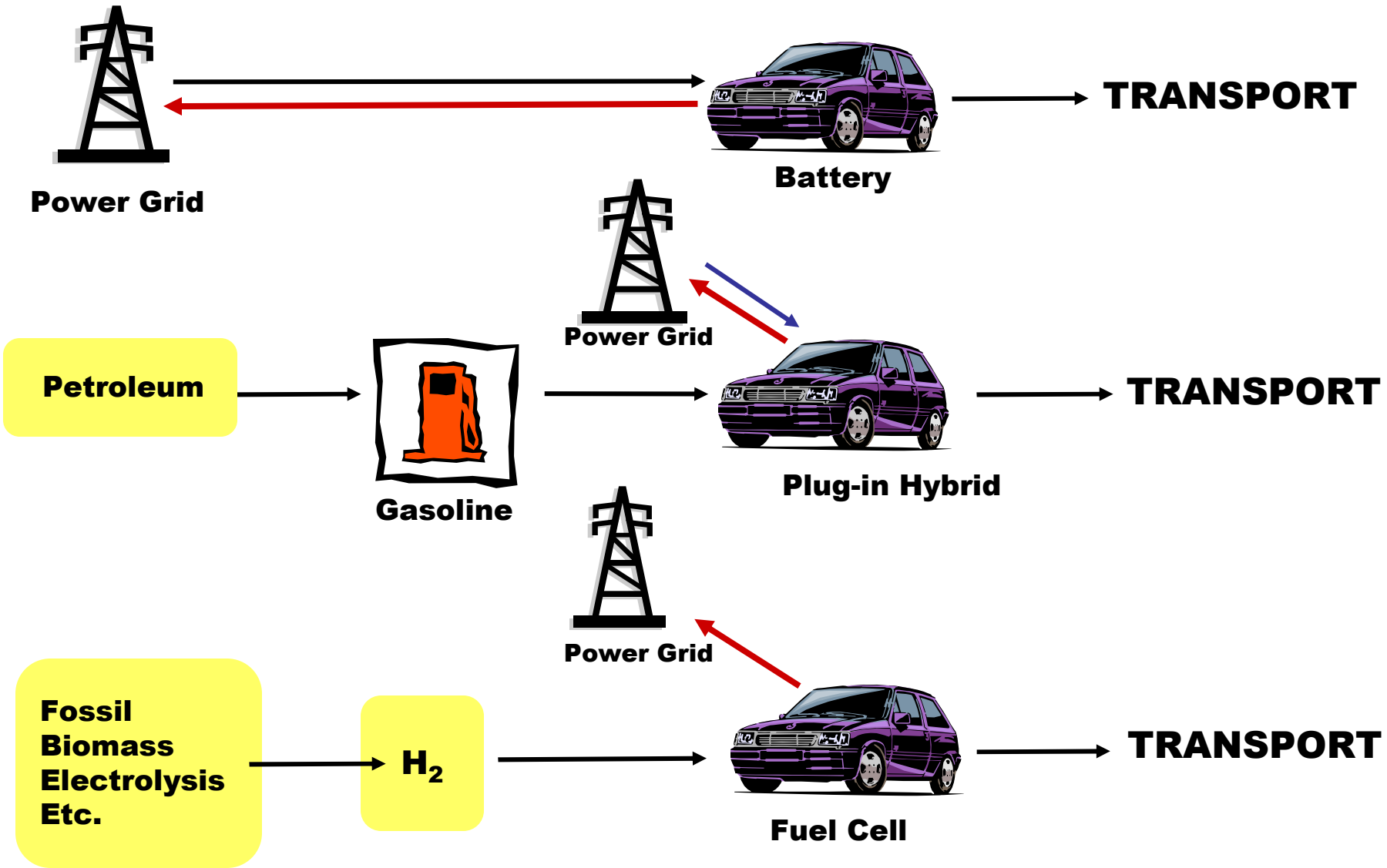
VEHICLE TYPES

Electric-drive Vehicles (EDV) means on-board power electronics producing AC power

- Battery: Full function & City Car
- Fuel Cell: On-board H_2 & stat. reformer
- Hybrid: ICE + battery

OUR PROPOSAL - V2G Power



Importance of V2G for ZEV

- Cost of full-function ZEVs is relatively high
- V2G provides revenue and helps offset that higher cost
- Dual use of ZEV for clean transportation and grid power support; shared capital cost
- Encourages early adoption of ZEVs

US POWER GRID vs EDV FLEET

	Power System	Vehicle Fleet	25% EDV
Units	9,500	200 mil	50 mil
Avg. unit power (kW)	64,000	111**	15 ***
System power (GW)	602*	22,200**	750
In-use factor	57%	~4%	4%+
Capital Cost (per kW)	$1,000+	$60	$10-200
Electricity Cost ($/kWh)	0.02-0.10 ave 0.05-0.80 peak		0.10-0.50

*Utility generators ** Mechanical ***Limited P line of home

Effect of EVs with V2G on Grid Infrastructure Requirements

- 50% of cars as EVs increase electric load ?
  - 100 Million cars
  - x 15,000 Miles per year / 4.8 Miles per kWh
  - = 312 Billion kWh per year at off-peak times
  - = 7 % of 2020 total national load

- With V2G, these EVs also provide a huge power resource:
  - 100 M cars * 15 kW * 0 .5 avail. = 750 GW of DG
  - > 70% of 2020 national electric power capacity!

Conclusion: Even 50% of cars as EV, IF they have V2G, probably REDUCE grid infrastructure requirements

(Calculation approach from Walter. Short, NREL, 2005)

How Can Electric Vehicles Benefit the Grid ?

- P of Vehicle Fleet > P of Electric Power System

  Grid-connected vehicle can provide:

- 1) Profitable Grid Management- Ancillary Services
- 2) Emergency power supply
- 3) Storage and integration with renewables (e.g. wind power)
- 4) Electric transit power support

EMERGENCY POWER

Emergency Grid power or local power supply

Benefits of V2G

- Very fast response
- Clean power source / replacing diesel generators
- Battery electric and some PHEV
- Grid backup, shared resource

Example: 1 vehicle with 20kW line connection could power 12 houses at average load of 1.5 kW/house.

Caution: May need to limit one car discharging at full power per pole-top “can” (typically 3 houses), can limit via software.

ELECTRIC VEHICLES - STORAGE FOR WIND AND SOLAR

- Use of Electric-drive vehicles with V2G could double wind resources (Short & Denholm 2006) or even enable 50% wind (Kempton &Tomic 2005)
- EDVs provide both ancillary services and diurnal storage for intermittent renewables (presentation by Murley & Kempton)

V2G FOR ELECTRIC TRANSIT POWER SUPPORT

- Typical urban rail profile: full power for 10 sec, 1/2 power for 20 sec more
- V2G can power traction spike for local rail
- Billing: demand charges, take-or-pay, pay own A/S, etc. Many cost savings possible.

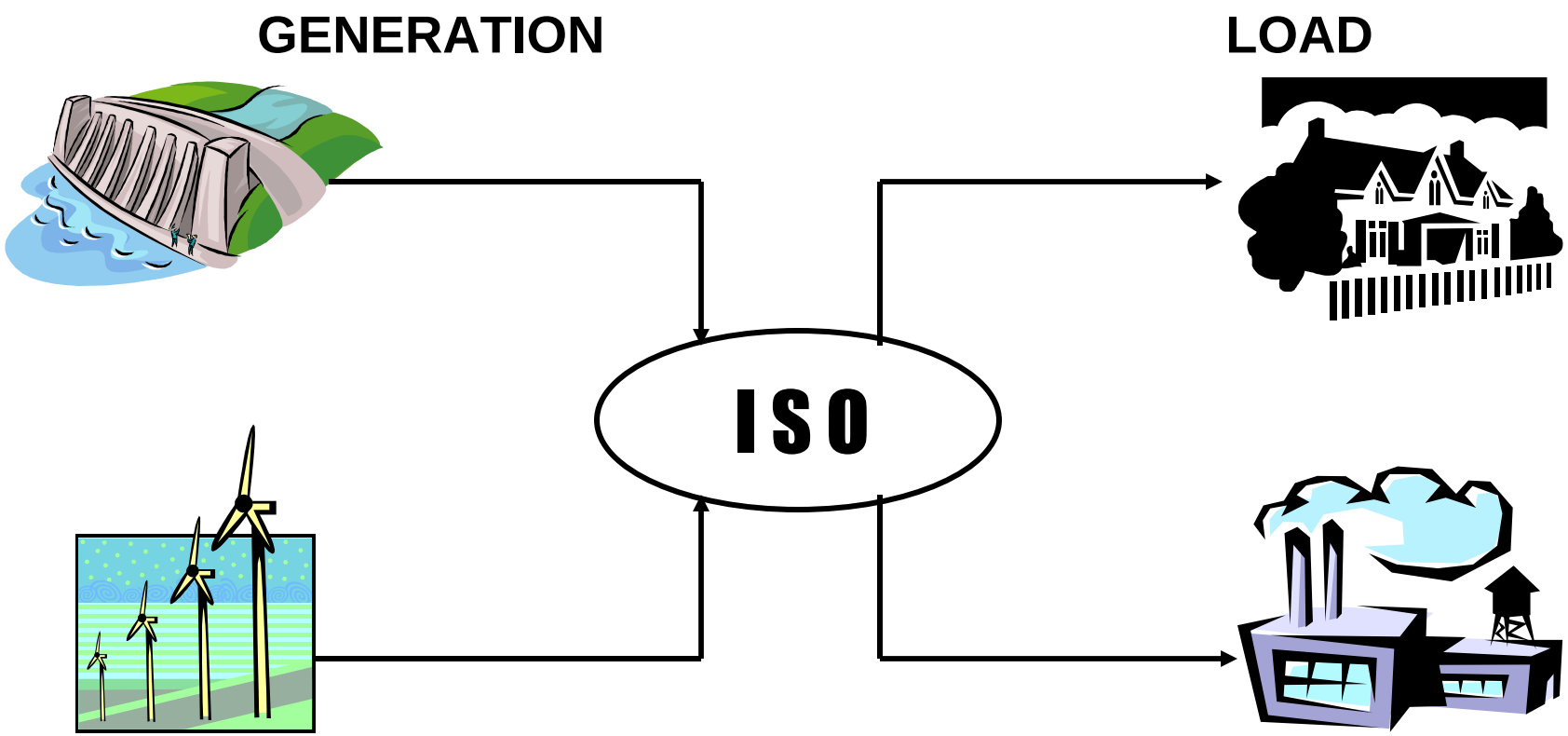
(presentation by Nishinaga this session)

V2G POWER FOR GRID MANAGEMENT - ANCILLARY SERVICES

- Ancillary Services (AS)
- Regulation Services
- Advantages of V2G for Regulation

- Utility EDV Fleets for Regulation Services
- Cost and Revenue Calculations
- Sample results of 2 fleet cases

Ancillary Services



- Grid Management- Maintain grid reliability
- Balance Supply and Demand
- Support transmission of electric power
- A/S requirements 5-10% of the system load

Ancillary Services

- **Regulation**: On-line generation synchronized to the grid to keep frequency and voltage steady. Energy is increased/decreased instantly (~ 2-3 min) via automatic generation control (AGC)

- **Spinning Reserves**: Additional generating capacity synchronized and ready to respond for ~10 min in case of failures.

- Payments consist of:
  Capacity price ($/MW-h) + Energy price ($/MWh)

Two Fleet Cases

- Cases use actual operating schedules (Tomic & Kempton n.d.)

A. New York Station Cars —

   100 Th!nk City EV

B. CA Utility Fleet —

   252 Toyota RAV4 EV

Fleet Case A
New York Station Cars

100

- For regulation services
- Upgrade cost for V2G included
- P_{line} = 6.2 kW
- t_{plug} = 23 h
- c_{el} = 0.05 $/kWh, c_{en} = 0.16 $/kWh

- NY ISO Regulation Capacity price

  p_{contr} = 27.5 $/MW-h (2003)

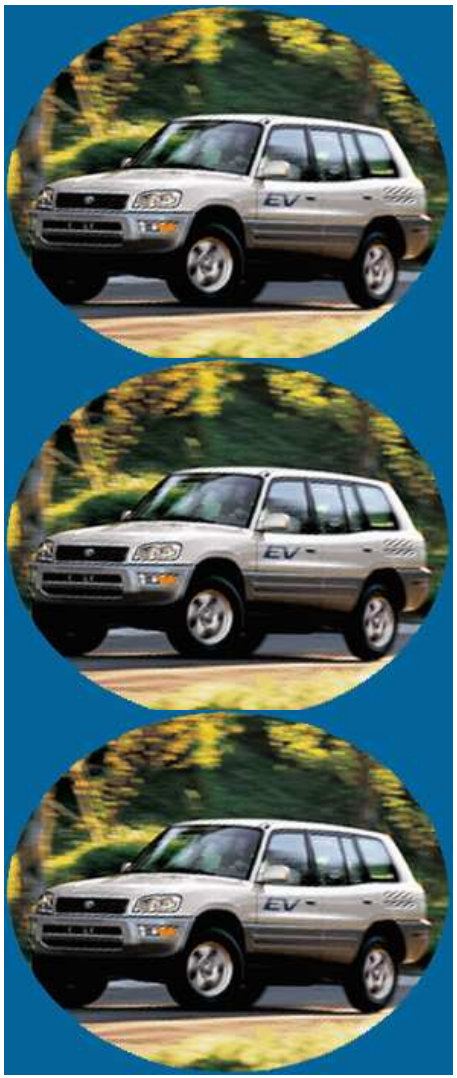
Calculated Profits

Case A

YEAR 2003			
FLEET POWER kW	Revenue	Cost	Net Profit
620	$ 311,700	$ 99,500	$ 212,200

Fleet Case B
Utility EDV Fleet

252



- For regulation services
- Upgrade costs for V2G included
- P_{line} = 15 kW
- t_{plug} = 17 h
- c_{el} = 0.05 $/kWh, c_{en} = 0.15 $/kWh

- CAISO Regulation Capacity price (2003)

  Reg_{up} p_{contr} = 19.5 $/MW-h

  Reg_{down} p_{contr} = 20.3 $/MW-h

Calculated Profits

Case B

YEAR 2003			
FLEET POWER kW	Revenue	Cost	Net Profit
@15 kW 3,780	$1,039,000	$380,000	$659,000

High power vehicles

- Tesla Motors, “Roadster”
  - 19 kW, 30 kWh, 200-250 mile range
- AC Propulsion Scion xB, “eBox”
  - 20 kW, 30 kWh, 200 mile range
  - In PJM territory, Delmarva calculates around $5,000/year in regulation A/S value!
- Both use AC motor, power electronics with AC output, thus high-power V2G function adds little to cost of vehicle.

Summary

- 2 fleet case analyses in different markets show significant economic potential for V2G providing A/S
  - Fleet of 100 small EDVs in NY
    Annual Revenue of $200,000
  - Fleet of 250 EDVs in CA
    Annual Revenue of $660,000

- Important parameters:
  - market value of A/S
  - kW capacity of vehicles and electrical connections
  - kWh capacity of vehicle battery

Conclusions

- V2G has high market value for regulation services and spinning reserves
- Possible early adopters: Utility fleets, cars parked at urban transit

CONCLUSIONS

- V2G can substantially bring down the cost of owning and operating ZEVs.
- High power connection favored, e.g. 20 kW, for short, high power grid support at little incremental cost.
- Benefits — clean transportation (no CO_2) and clean source of electric power.

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More information: www.udel.edu/V2G

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